



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
**21.02.2018 Bulletin 2018/08**

(21) Application number: **17153851.5**

(22) Date of filing: **30.01.2017**

(51) Int Cl.:  
**C02F 1/44** (2006.01) **B01D 61/00** (2006.01)  
**C02F 103/36** (2006.01) **C02F 103/06** (2006.01)  
**C02F 103/10** (2006.01) **C02F 1/20** (2006.01)  
**C02F 1/52** (2006.01) **C02F 101/32** (2006.01)

(84) Designated Contracting States:  
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**  
Designated Extension States:  
**BA ME**  
Designated Validation States:  
**MA MD**

(30) Priority: **16.08.2016 US 201615238284**

(71) Applicant: **Linde Aktiengesellschaft**  
**80331 München (DE)**

(72) Inventor: **ASLAM, Naveed**  
**Houston, TX 77030 (US)**

(74) Representative: **Hofmann, Andreas et al**  
**RGTH**  
**Patentanwälte PartGmbB**  
**Postfach 33 02 11**  
**80062 München (DE)**

(54) **METHOD FOR TREATING PRODUCED WATER WITH FORWARD OSMOSIS**

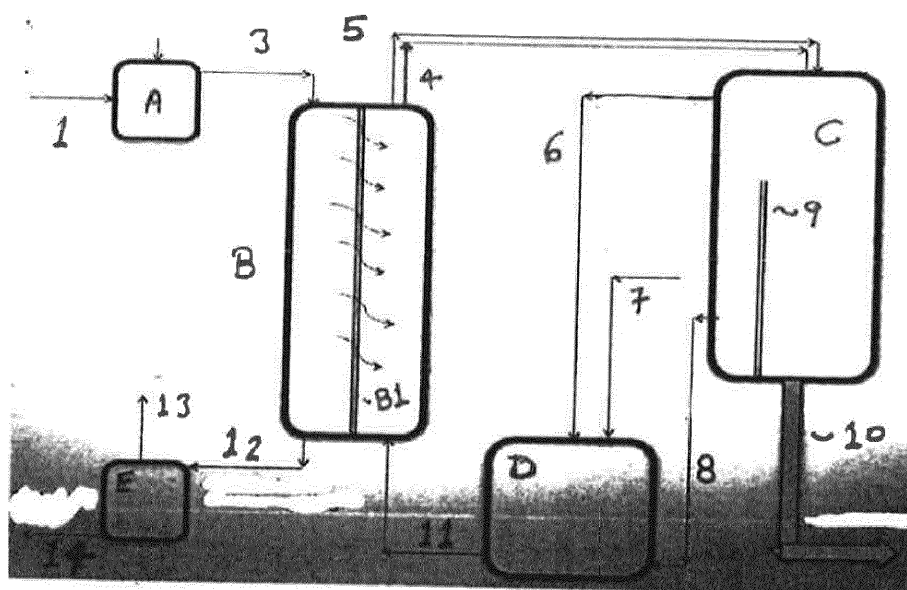
(57) In order to overcome the limitations and problems that earlier methods have experienced, a method for treating produced water is proposed, comprising the steps of:

- a) mixing (A) nitrogen and produced water and feeding the mixture to a forward osmosis unit (B) containing a semi-permeable membrane (B1);
- b) feeding carbon dioxide gas to the forward osmosis unit

(B), therein creating a pressurized nitrogen side and a pressurized carbon dioxide side of the forward osmosis unit (B);

c) recovering concentrated produced water from the pressurized nitrogen side of the forward osmosis unit (B); and

d) recovering fresh water from the pressurized carbon dioxide side of the forward osmosis unit (B).



**FIG. 1**

**Description****Technical field of the present invention**

5 [0001] The present invention relates to a method for treating produced water.

**Technological background of the present invention**

10 [0002] Hydraulic fracturing is becoming a desirable method for extracting hydrocarbons. However, this method is being given scrutiny by public and regulatory agencies due to their extensive requirement for and consumption of water.

[0003] This problem is exacerbated, for example in certain regions of the United States, because there is a water shortage to contend with. For example the Permian Basin in Texas is one such area so there is a continuous need for methods that use water more efficiently in the hydraulic fracturing operations.

15 **Disclosure of the present invention: object, solution, advantages**

[0004] Starting from the disadvantages and shortcomings as described above as well as taking the prior art as discussed into account, an object of the present invention is to overcome the limitations and problems that earlier methods have experienced.

20 [0005] This object is accomplished by a method comprising the features of claim 1. Advantageous embodiments, expedient improvements and other optional features of the present invention are set forth herein and disclosed in the respective dependent claims.

[0006] The present invention basically provides for a method for reclaiming produced water and utilizes a forward osmosis unit to concentrate and produce fresh water from oil and gas produced water using feeds of nitrogen and carbon dioxide to the forward osmosis unit.

25 [0007] More particularly, a method for treating produced water from a fracking source is disclosed. The method first mixes nitrogen and produced water and feeds the mixture to a forward osmosis unit containing a semi-permeable membrane; carbon dioxide gas is then fed to the forward osmosis unit, therein creating a pressurized nitrogen side and a pressurized carbon dioxide side of the forward osmosis unit; concentrated produced water is recovered from the pressurized nitrogen side of the forward osmosis unit and fresh water is recovered from the pressurized carbon dioxide side of the forward osmosis unit.

[0008] In one embodiment of the present invention, there is disclosed a method for treating produced water comprising the steps of:

- 35 a) mixing nitrogen and produced water and feed the mixture to a forward osmosis unit containing a semi-permeable membrane;
- b) feeding carbon dioxide gas to the forward osmosis unit, therein creating a pressurized nitrogen side and a pressurized carbon dioxide side of the forward osmosis unit;
- 40 c) recovering concentrated produced water from the pressurized nitrogen side of the forward osmosis unit; and
- d) recovering fresh water from the pressurized carbon dioxide side of the forward osmosis unit.

[0009] According to an advantageous embodiment of the present invention, the nitrogen and the carbon dioxide gases that are fed to the forward osmosis unit in steps a) and b) above may be at high pressure.

45 [0010] In an expedient embodiment of the present invention, this high pressure may be between about 0.5 MPa to about 3 MPa (about five bar to about thirty bar).

[0011] According to a favoured embodiment of the present invention, the nitrogen may be replaced by an inert gas selected from the group consisting of helium, argon and mixtures thereof.

[0012] In a preferred embodiment of the present invention, the water from the produced water may be driven through the semi-permeable membrane. The semi-permeable membrane may allow for the passage of certain molecules and not others.

50 [0013] According to an advantageous embodiment of the present invention, the semi-permeable membrane may be made

- from polymers with special coatings, in particular from poly imides, and/or
- 55 - from carbonates, in particular from polyvinyl carbonates.

[0014] In an expedient embodiment of the present invention, the concentrated produced water that may be recovered from the pressurized nitrogen side of the forward osmosis unit may be fed to a concentrator which may separate the

nitrogen gas dissolved in the concentrated produced water from the concentrated produced water.

**[0015]** According to a favoured embodiment of the present invention, the fresh water that may be recovered from the pressurized carbon dioxide side of the forward osmosis unit may be fed to a separation device.

**[0016]** In a preferred embodiment of the present invention, recovered carbon dioxide gas from the pressurized carbon dioxide side of the forward osmosis unit may also be fed to the separation device.

**[0017]** In the forward osmosis unit, the osmotic pressure in the produced water may be lower due to the presence of salts therein. Conversely, the osmotic pressure in the gas driven draw solution may be higher. This may create a driving force within the forward osmosis unit. This driving force may make the water from the produced water move into the draw solution in its attempt to lower its osmotic pressure. In this manner, the water may be separated through the natural driving force unlike reverse osmosis for example where hydraulic pressure may be increased through the use of the pump.

**[0018]** According to an advantageous embodiment of the present invention, the fresh water may be further separated as such from the carbon dioxide gas in the separation device and recovered, in particular for reuse or as potable water.

**[0019]** In an expedient embodiment of the present invention, the carbon dioxide gas separated out may be fed to a concentrator unit where this recovered carbon dioxide gas may combine with a feed of pressurized carbon dioxide gas for feed into the pressurized carbon dioxide side of the forward osmosis unit.

**[0020]** According to a favoured embodiment of the present invention, Phase II liquid may also be recovered from the separation device and fed to a concentrator unit.

**[0021]** In a preferred embodiment of the present invention, the Phase II liquid may provide enhanced solubility of carbon dioxide.

**[0022]** According to an advantageous embodiment of the present invention, the Phase II liquid when fed to a concentrator, may form a two phase draw solution which under pressure from a carbon dioxide fresh feed may be fed to the forward osmosis unit for separation of water from the produced water.

**[0023]** In an expedient embodiment of the present invention, the concentrated produced water from the concentrator may be fed to a crystallizer or may be discharged.

**[0024]** According to a favoured embodiment of the present invention, the concentrator unit may adjust the concentrations of solutes in a draw solution.

**[0025]** In a preferred embodiment of the present invention, a gravity separator may be present in the separation unit.

**[0026]** The methods of the present invention are applicable to any produced water with produced waters having lower concentrations of contaminants preferred.

**[0027]** The average produced water composition is described as follows: i.e., minimum, maximum and average:

| constituent:                | average: | maximum: | minimum: |
|-----------------------------|----------|----------|----------|
| COD (mg/l)                  | 3,000    | 7,900    | 300      |
| pH                          | 7        | 8        | 6        |
| TDS (mg/l)                  | 150,000  | 400,000  | 1,000    |
| TSS (mg/l)                  | 1,200    | 13,800   | 10       |
| O&G (mg/l)                  | 800      | 1,000    | 600      |
| iron (mg/l)                 | 100      | 300      | 3        |
| barium (mg/l)               | 1,600    | 9,000    | 1        |
| strontium (mg/l)            | 2,000    | 6,300    | 40       |
| sulfate (mg/l)              | 1,200    | 15,000   | 10       |
| sodium (mg/l)               | 36,000   | 150,000  | 3,300    |
| chlorine (mg/l)             | 88,000   | 250,000  | 5,000    |
| bicarbonate (mg/l)          | 1,800    | 15,000   | 80       |
| calcium (mg/l)              | 10,200   | 74,000   | 300      |
| total organic carbon (mg/l) | 800      | 7,200    | 60       |

**[0028]** According to an advantageous embodiment of the present invention, the produced water may be characterized by very high dissolved salts and/or dissolved solids. On average, these amounts of dissolved salts and/or of dissolved solids may be around 150,000 p[arts]p[er]m[illion]. With this amount of dissolved salts and/or of dissolved solids, produced water is typically beyond the capabilities of a traditional reverse osmosis (RO) unit.

#### Brief description of the drawings

**[0029]** For a more complete understanding of the present embodiment disclosures and as already discussed above, there are several options to embody as well as to improve the teaching of the present invention in an advantageous

manner. To this aim, reference may be made to the claims dependent on claim 1; further improvements, features and advantages of the present invention are explained below in more detail with reference to particular and preferred embodiments by way of non-limiting example and to the appended drawing figure taken in conjunction with the following description of exemplary embodiments, of which:

FIG. 1 is a schematic of a method for producing and concentrating fresh water from oil and gas produced water according to the present invention.

## Detailed description of the drawings;

### best way of embodying the present invention

[0030] Before explaining the inventive embodiments in detail, it is to be understood that the present invention is not limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the present invention is capable of other embodiments and being practiced or carried out in various ways. Also, it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

[0031] In the description above and below, terms such as horizontal, upright, vertical, above, below, beneath and the like, are used solely for the purpose of clarity illustrating the present invention and should not be taken as words of limitation. The drawings are for the purpose of illustrating the present invention and are not intended to be to scale.

[0032] Turning to FIG. 1, a method for treating produced water from an oil and gas source is shown. Produced water is fed through line 1 to a mixing chamber A where it will be mixed with high pressure nitrogen fed through line 2. The produced water will contain a number of impurities including particulate materials and hydrocarbons from the well and any fracing treatments.

[0033] The mixture of produced water and high pressure nitrogen is fed from mixing chamber A to a forward osmosis unit B which contains a semi-permeable membrane B1. The effects of this forward osmosis unit B is to drive by way of osmotic pressure to separate the feed of produced water from the solutes present therein.

[0034] As such, a concentrated solution of produced water will be fed through line 12 to a concentrator E. This concentrated solution of produced water also contains some nitrogen which will be vented from the concentrator E through line 13. The concentrated produced water from concentrator E can be fed to a crystallizer or it can be discharged and disposed of.

[0035] The concentrator E will produce concentrated produced water which will be fed through line 14 for further treatment. The concentrator units in general will adjust the concentrations of solutes in the draw solution for reliable operation of the forward osmosis unit B.

[0036] Pressurized carbon dioxide gas is fed through line 7 to a concentrator D which will also receive through line 8 Phase II liquid a separation device C. The pressurized carbon dioxide will dissolve in the Phase II liquid and be fed through line 11 to the forward osmosis unit B.

[0037] Because the carbon dioxide will provide higher osmotic pressure on the carbon dioxide side of the semi-permeable membrane, the fresh water from the produced water will diffuse into the carbon dioxide side of the forward osmosis unit B. This fresh water is recovered and fed through line 4 to the separation device C.

[0038] The separation unit C will separate phases. For example, fresh water being relatively heavier will settle at the bottom while the organic draw solution, being relatively lighter floats on the water layer. This organic draw solution can be mixed with fresh carbon dioxide to be recycled for further drawing of the water from the produced water.

[0039] Carbon dioxide gas will also be recovered from the carbon dioxide side of the semi-permeable membrane and be fed through line 5 to the separation device C. A gravity separator 9 is present in the separation unit C.

[0040] The separation device C will separate the fresh water from the Phase II liquid and be recovered through line 10 for reuse in the fracing operation or as potable water. Carbon dioxide gas which has been separated will be fed through line 6 to the concentrator D where it can join with the pressurized carbon dioxide gas fed through line 7 into the concentrator D thereby supplementing the amount of fresh pressurized carbon dioxide gas needed.

[0041] It will be understood that the embodiments described herein are merely exemplary, and that one skilled in the art may make variations and modifications without departing from the spirit and scope of the present invention. All such variations and modifications are intended to be included within the scope of the present invention as described and claimed herein. Further, all embodiments disclosed are not necessarily in the alternative, as various embodiments of the present invention may be combined to provide the desired result.

## List of reference signs

[0042]

- 1 line or pipe or tube for feeding or introducing produced water to mixing chamber A  
 2 line or pipe or tube for feeding or introducing nitrogen, in particular high pressure nitrogen, to mixing chamber A  
 3 line or pipe or tube from mixing chamber A to forward osmosis unit B  
 4 line or pipe or tube from forward osmosis unit B to separation device or separation unit C for feeding fresh water  
 5 5 line or pipe or tube from forward osmosis unit B to separation device or separation unit C for feeding carbon dioxide gas  
 6 line or pipe or tube from separation device or separation unit C to concentrator D for feeding carbon dioxide gas  
 7 line or pipe or tube from separation device or separation unit C to concentrator D for feeding pressurized carbon dioxide gas  
 10 8 line or pipe or tube from separation device or separation unit C to concentrator D for feeding Phase II liquid  
 9 gravity separator  
 10 line or pipe or tube from separation device or separation unit C  
 11 line or pipe or tube from concentrator D to forward osmosis unit B  
 12 line or pipe or tube from forward osmosis unit B to concentrator E  
 15 13 line or pipe or tube from concentrator E for venting nitrogen  
 14 line or pipe or tube from concentrator E for concentrated produced water  
 A mixing chamber  
 B forward osmosis unit  
 B1 semi-permeable membrane of forward osmosis unit B  
 20 C separation device or separation unit  
 D concentrator unit  
 E concentrator

## 25 Claims

1. A method for treating produced water, comprising the steps of:
- 30 a) mixing (A) nitrogen and produced water and feeding the mixture to a forward osmosis unit (B) containing a semi-permeable membrane (B1);  
 b) feeding carbon dioxide gas to the forward osmosis unit (B), therein creating a pressurized nitrogen side and a pressurized carbon dioxide side of the forward osmosis unit (B);  
 c) recovering concentrated produced water from the pressurized nitrogen side of the forward osmosis unit (B); and  
 35 d) recovering fresh water from the pressurized carbon dioxide side of the forward osmosis unit (B).
2. The method according to claim 1 wherein the nitrogen and the carbon dioxide that are fed to the forward osmosis unit (B) in steps a) and b) are at high pressure, in particular between about 0.5 MPa to about 3 MPa (about five bar to about thirty bar).
- 40 3. The method according to claim 1 or 2 wherein the nitrogen is replaced with an inert gas selected from the group consisting of helium, argon and mixtures thereof.
4. The method according to at least one of claims 1 to 3 wherein the water from the produced water is driven through the semi-permeable membrane (B1).
- 45 5. The method according to at least one of claims 1 to 4 wherein the semi-permeable membrane (B1) is made
- from polymers with special coatings, in particular from poly imides, and/or
  - from carbonates, in particular from polyvinyl carbonates.
- 50 6. The method according to at least one of claims 1 to 5 wherein the concentrated produced water that is recovered from the pressurized nitrogen side of the forward osmosis unit (B) is fed to a concentrator (E) for separating the nitrogen gas dissolved in the concentrated produced water from the concentrated produced water.
- 55 7. The method according to claim 6 wherein the concentrated produced water from the concentrator (E) is fed to a crystallizer or is discharged.
8. The method according to at least one of claims 1 to 7 wherein

### EP 3 284 726 A1

- the fresh water that is recovered from the pressurized carbon dioxide side of the forward osmosis unit (B), and/or
  - recovered carbon dioxide gas from the pressurized carbon dioxide side of the forward osmosis unit (B)
- are/is fed to a separation device (C), in particular comprising a gravity separator (9).

- 5     **9.** The method according to claim 8 wherein the fresh water is further separated from the carbon dioxide gas in the separation device (C) and recovered, in particular for reuse or as potable water.
- 10    **10.** The method according to claim 8 or 9 wherein Phase II liquid is recovered from the separation device (C) and fed to a concentrator unit (D).
- 15    **11.** The method according to claim 10 wherein the concentrator unit (D) adjusts the concentrations of solutes in a draw solution.
- 20    **12.** The method according to claim 10 or 11 wherein the Phase II liquid provides enhanced solubility of carbon dioxide.
- 25    **13.** The method according to at least one of claims 10 to 12 wherein the Phase II liquid forms a two phase draw solution which under pressure from a carbon dioxide feed is fed to the forward osmosis unit (B).
- 30    **14.** The method according to at least one of claims 1 to 13 wherein the recovered carbon dioxide gas is combined with pressurized carbon dioxide gas before being fed to the pressurized carbon dioxide side of the forward osmosis unit (B).
- 35    **15.** The method according to at least one of claims 1 to 14 wherein the produced water contains about 150,000 parts per million dissolved salts and/or dissolved solids.
- 40
- 45
- 50
- 55

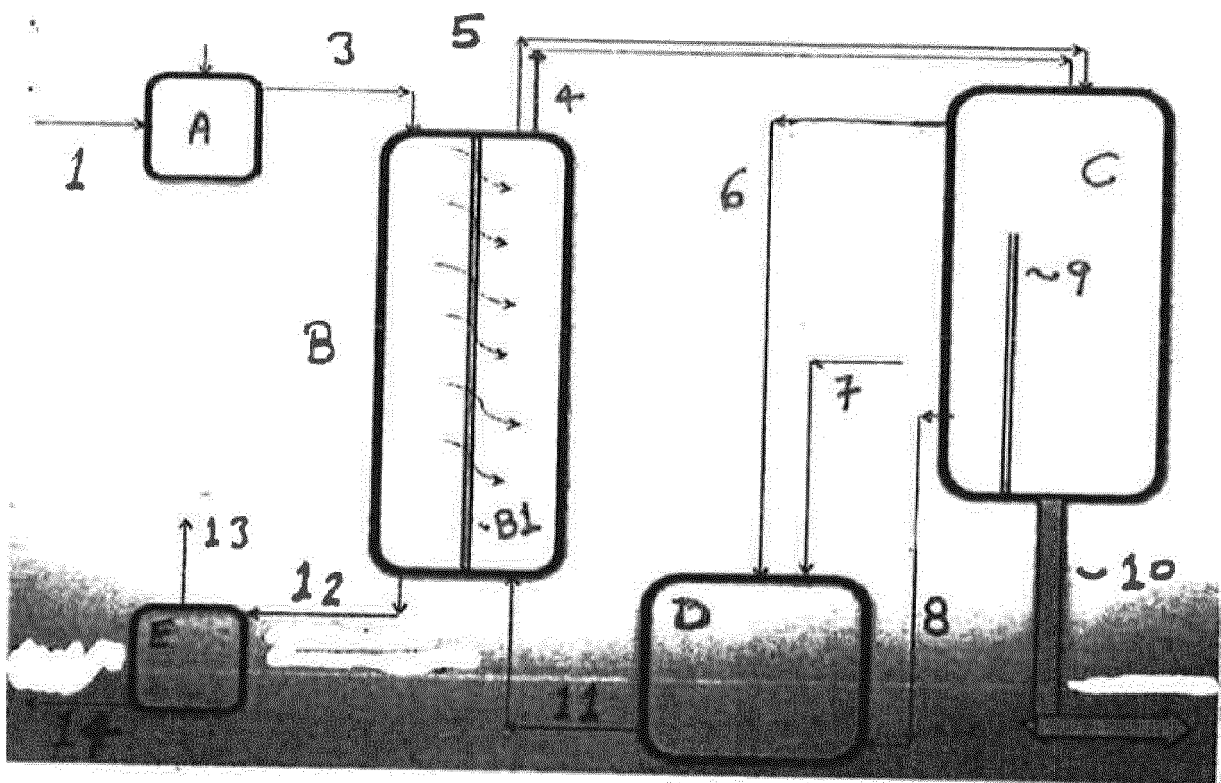


FIG. 1



## EUROPEAN SEARCH REPORT

Application Number  
EP 17 15 3851

5

10

15

20

25

30

35

40

45

50

55

| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                   |                                                   |                                                                                      |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------|--------------------------------------------------------------------------------------|
| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Citation of document with indication, where appropriate, of relevant passages                                                                                                                                                                                                                                                                                                                     | Relevant to claim                                 | CLASSIFICATION OF THE APPLICATION (IPC)                                              |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | WO 2016/094835 A1 (ARTESION INC [US])<br>16 June 2016 (2016-06-16)<br>* paragraphs [0003], [0068], [0099],<br>[0100], [0146], [0147], [0164],<br>[0165], [0211]; claim 30; figure 1 *                                                                                                                                                                                                             | 1-15                                              | INV.<br>C02F1/44<br>B01D61/00                                                        |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | US 2015/175447 A1 (SENGUPTA ARUP [US] ET AL)<br>25 June 2015 (2015-06-25)<br>* paragraphs [0008], [0011], [0029],<br>[0030], [0035], [0044]; claim 1; figure 7 *                                                                                                                                                                                                                                  | 1-15                                              | ADD.<br>C02F103/36<br>C02F103/06<br>C02F103/10<br>C02F1/20<br>C02F1/52<br>C02F101/32 |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | JAMIL SHAZAD ET AL: "Application of pressure assisted forward osmosis for water purification and reuse of reverse osmosis concentrate from a water reclamation plant",<br>SEPARATION AND PURIFICATION TECHNOLOGY, ELSEVIER SCIENCE, AMSTERDAM, NL, vol. 171, 25 July 2016 (2016-07-25), pages 182-190, XP029707096,<br>ISSN: 1383-5866, DOI: 10.1016/J.SEPPUR.2016.07.036<br>* paragraph [0001] * | 1-15                                              | TECHNICAL FIELDS SEARCHED (IPC)<br>B01D<br>C02F                                      |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | MASAFUMI SHIBUYA ET AL: "Effects of operating conditions and membrane structures on the performance of hollow fiber forward osmosis membranes in pressure assisted osmosis",<br>DESALINATION., vol. 365, 1 June 2015 (2015-06-01), pages 381-388, XP055365928, NL<br>ISSN: 0011-9164, DOI: 10.1016/j.desal.2015.03.005<br>* paragraph [0001]; figure 1 *                                          | 1-15                                              |                                                                                      |
| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                   |                                                   |                                                                                      |
| Place of search<br>The Hague                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                   | Date of completion of the search<br>21 April 2017 | Examiner<br>Fiocchi, Nicola                                                          |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br>T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |                                                                                                                                                                                                                                                                                                                                                                                                   |                                                   |                                                                                      |

EPO FORM 1503 03.82 (P04C01)



## EUROPEAN SEARCH REPORT

Application Number  
EP 17 15 3851

5

10

15

20

25

30

35

40

45

50

55

| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                           |                                                   |                                         |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------|-----------------------------------------|
| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Citation of document with indication, where appropriate, of relevant passages                                             | Relevant to claim                                 | CLASSIFICATION OF THE APPLICATION (IPC) |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | US 2015/329398 A1 (MINNICH KEITH R [CA] ET AL) 19 November 2015 (2015-11-19)<br>* paragraphs [0069] - [0070]; figure 3b * | 7                                                 |                                         |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | US 2016/046360 A1 (KIM SUNG HOON [KR] ET AL) 18 February 2016 (2016-02-18)<br>* paragraphs [0051] - [0057]; figure 2 *    | 8                                                 |                                         |
| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                           |                                                   | TECHNICAL FIELDS SEARCHED (IPC)         |
| Place of search<br>The Hague                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                           | Date of completion of the search<br>21 April 2017 | Examiner<br>Fiocchi, Nicola             |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br>T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |                                                                                                                           |                                                   |                                         |

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 17 15 3851

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
The members are as contained in the European Patent Office EDP file on  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

21-04-2017

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s)                            | Publication<br>date                    |
|-------------------------------------------|---------------------|-------------------------------------------------------|----------------------------------------|
| WO 2016094835 A1                          | 16-06-2016          | NONE                                                  |                                        |
| US 2015175447 A1                          | 25-06-2015          | US 2015175447 A1<br>WO 2015100087 A1                  | 25-06-2015<br>02-07-2015               |
| US 2015329398 A1                          | 19-11-2015          | CA 2891199 A1<br>US 2015329398 A1                     | 13-11-2015<br>19-11-2015               |
| US 2016046360 A1                          | 18-02-2016          | EP 3018104 A1<br>KR 20160020602 A<br>US 2016046360 A1 | 11-05-2016<br>24-02-2016<br>18-02-2016 |